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(54) **High spatial resolution imaging spectrograph**

Abbildender Spektralapparat mit hoher örtlicher Auflösung

Spectrographe d'image à haute résolution spatiale

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multichannel spectrograph, and, more particularly, to a spectrograph optimized to provide the largest possible number of independent spatial channels in the vertical plane and more modest spectral resolution in the horizontal plane.

2. Description of the Related Art

Spectrographs, and more recently scanning monochromators, have been in use for some time in an increasingly large number of applications. However, until quite recently, these instruments were limited to gathering and processing information through one channel. Light entered the instrument from a single source, and the instrument physically separated the light according to its wavelengths and presented as the output a single spectrum, most often dispersed in the horizontal plane.

In theory, nothing would have prevented the designers of early instruments, built around a prism as a dispersive element, to fashion a multichannel instrument, since they had good imaging properties due to their dioptric input and output optical systems working on axis. For each wavelength, the same point of the entrance slit was imaged as a different point in the image field. This presented the opportunity of using several spatially distinct sources of light at the input to obtain several distinguishable spectra in the image plane of a single instrument. However, in practice the modest sensitivity of early detectors as well as the small apertures (f/16 or less) of these early instruments forced designers to improve throughput at the cost of spatial resolution by introducing the concept of the entrance slit placed perpendicular to the axis of dispersion.

Later, when reflection gratings were introduced, allowing for easy extension into the UV and IR parts of the optical spectrum, dioptric optics were replaced by mirrors, which are easy to produce with broad band reflectivity. While dioptric optics work naturally on axis, mirrors are easier to use at an angle leading to very large astigmatic deformation of the image, an effect that becomes very important with fast instruments which require wide open beams and closely packaged elements.

An elegant approach to solve the astigmatic deformation of the image has been to ignore it by using the plane of the tangential focus as the image plane. In this configuration, a point of the object plane is transformed into a vertical line and a vertical slit into a slightly longer vertical image, which preserves spectral resolution. As a result, the instrument keeps a good spectral resolution at the cost of spatial resolution. This is of no consequence in applications where the only concern is measuring the spectral properties of a single sample. However, there are an ever growing listing of applications which would benefit from both spectral and spatial information.

The advent of two dimensional arrays of high quantum efficiency detectors, such as modern charge-coupled-device (CCD) and charge-injection-device (CID) 2-D detectors, and optical fibers to transport light has suggested the desirability of using spectrographs as multichannel dispersive systems capable of generating independent spectra of different sources. However, multispectra systems require a spectrograph capable of spectrally dispersing light along one axis while maintaining the spatial integrity of the- input image vertically. In other words, the spectrum produced at one height at the focal plane of the spectrograph should be from one point at the corresponding height at the entrance slit.

The construction of such a spectrograph poses a challenge to designers. Conventional designs suffer from vignetting, astigmatism, coma, and other sources of crosstalk that destroy spatial purity of the resulting image at the focal plane. In recent years manufacturers have begun the introduction of high performance spectrographs allowing for some astigmatism correction and opening the field of multichannel spectroscopy. In 1989, CHROMEX Inc., of Albuquerque, New Mexico, introduced the FF-250/FF-500 family of fast (f/4) spectrographs, which use toroidal mirrors, instead of spherical mirrors, to correct astigmatism of the instrument. This advance allows the instruments to become multichannel instruments, particularly useful for multichannel applications while remaining capable of performing spectral measurements with the same resolution as their more conventional counterparts.

These improved instruments remain spectrographs primarily optimized for high spectral resolution in,the horizontal direction. The astigmatic correction provided by toroidal mirrors allows for a limited number of independent spatial channels, probably more than enough for most applications, but cannot provide for high spatial resolution compatible with good imaging. This is the case because today fast instruments have by nature a high degree of astigmatism that can be corrected only in a narrow range of angles. Furthermore, the image field of these instruments has by design a high degree of curvature further limiting spatial resolution.

For an increasing number of new survey applications, where high spectral resolution is not usually needed, it is desirable to have a multichannel spectrograph which is optimized for the highest possible spatial resolution in the vertical plane and a more modest spectral resolution. Particularly important uses for such an instrument are in high resolution, remote sensing of earth resources, in infrared imaging, and in microscopy.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a high resolution fast imaging spectrograph which is designed specifically to provide greatly enhanced spatial resolution while maintaining sufficient spectral resolution for a variety of applications. In particular, in accordance with the present invention, a high spatial resolution imaging spectrograph is provided which will provide greatly enhanced spatial resolution for land and sea remote sensing.

Another object of the present invention is to provide a high spatial resolution imaging spectrograph capable of continuous high speed measurement of spectral distribution information simultaneously at hundreds of points in a sample.

It is a further object of the present invention to provide a high spatial resolution imaging spectrograph which is lightweight and compact, having no power requirements and no operating controls or adjustments.

It is a further object of the present invention to provide a high spatial resolution imaging spectrograph which allows for remote light gathering by means of a optical fiber cable or ribbon or a conventional optical system.

These objects are achieved by the imaging spectrographs claimed in the independent claims. Advantageous embodiments of the invention are described in the dependent claims.

Other objects, features, and characteristics of the present invention, as well as the methods of operation and functions of the related elements of the structure, and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a pictorial representation of the image field, defined in terms of high spectral but limited spatial channels of information, found in a high resolution imaging spectrograph of the most recent design, such as the CHROMEX instruments;

FIGURE 2 is a pictorial representation ot the image field, defined in terms of high spatial but limited spectral channels of information, found in a high spatial imaging spectrograph in accordance with the present invention;

FIGURE 3 is an optical ray path view along the cross-track axis of a preferred embodiment of a high spatial resolution imaging spectrograph in accordance with the present invention;

FIGURE 4 is an optical ray path view along the cross-track axis of an alternative preferred embodiment of a high spatial resolution imaging spectrograph according to the present invention;

FIGURE 5 is a pictorial representation of a significant commercial application of the high spatial resolution spectrograph in accordance with the present invention, showing an earth science remote imaging system comprising a high spatial resolution imaging spectrograph and a telescope connected to the spectrograph by means of an optical fiber ribbon;

FIGURE 6 is an elevational view of a collimating mirror showing the placement of an optical mask in front of the mirror;

FIGURE 7 is a cut-away sectional view of the mirror of FIGURE 6 further showing the placement of a mask in front of the mirror.

DETAILED DESCRIPTION OF PRESENTLY PREFERRED EMBODIMENTS

As illustrated in FIGURE 1, modern high resolution multichannel spectrographs are designed to provide the largest possible number of independent spectral channels in the horizontal direction and only limited spatial resolution in the vertical. It is impossible for such spectrographs to provide high spatial resolution because modern fast instruments have a high degree of astigmatism which can be adequately corrected only in a narrow range of angles. Furthermore, the image field of these instruments has by design a high degree of curvature further limiting their spatial resolution. Commonly such instruments can achieve 500 spectral channels at the spectrograph output focal plane. Each such spectral channel is resolved into a maximum of 40 spatial channels across-a wavelength range, which is defined by the grating used.

As illustrated in FIGURE 2, a high spatial resolution imaging spectrograph in accordance with the present invention provides the highest possible spatial resolution in the vertical plane at the expense of more modest spectral resolution. An instrument of the present invention can achieve 400 to 1000 spatial channels at the spectrograph output focal plane. Each such spatial channel is resolved into 100 spectral channels across a wavelength range of, for example, 400-800 nm.

An approximate expression of the situation is that an optical system based on a given set of components and providing a given throughput cannot transfer more than a given number of information channels. This number is, because of different aberrations, smaller than-what diffraction would ultimately allow. The information channels can be arranged either to privilege the horizonal, or spectral, direction (as is the case for modern and conventional spectrographs) or the vertical, or spatial, direction (as is the case for a spectrograph in accordance with the present invention).

A high spatial resolution imaging spectrograph provided in accordance with the present invention can be seen in FIGURE 3. Illustrated is a ray-path schematic view of an f/4 instrument capable of providing 400 spatial channels and 100 spectral channels across a wavelength range of 400 to 800 nm.

A collimating mirror 10 and a focusing mirror 12 are illustrated, each permanently attached to the base of the spectrograph. The mirrors are conventional 110 mm diameter spherical mirrors with a focal length of 250 mm facing a plane diffraction grating 14. The grating is also permanently affixed to the base of the spectrograph and at an acute angle θ to the perpendicular to the optic axis. The angle θ is somewhat dependent upon the grating selected in order not to work too far from the Littrow configuration, which allows for maximum throughput. Typically, θ will be in the range of 5 to 35 degrees depending on the groove density of the grating. The grating 14 is approximately 60 x 60 mm in size. An elongated slot 16, 4 x 20 mm in size, is cut through approximately the center of the grating 14, allowing the light source 18 to pass through the slot 16 and onto collimating mirror 10. The light source 18 is placed at the focus of the collimating mirror 10 and at a point where radiation can illuminate the collimating mirror.

Turning mirror 20 is a plane mirror, 10 x 20 mm in size, which also is fixed to the base of the spectrograph and positioned to reflect light from the focus of the focusing mirror 12 onto the camera mirror 22. The turning mirror is positioned as close as possible to the elongated slot 16, thus receiving an image as close as possible to the object. This placement of the turning mirror allows the spherical mirrors to work "almost on axis" in an angular range where angular dependent aberrations, particularly astigmatism, are negligible.

The camera mirror 22 is a conventional 110 mm diameter spherical mirror with a focal length of 150 mm which focuses a final image 25 mm outside the instrument enclosure onto a detector 24. As with the other instrument components, the camera mirror is also fixed to the base of the spectrograph and works "almost on axis".

The light source to the instrument is preferably provided by an optical fiber ribbon, with individual fiber diameters commonly in a range of 7-250 microns. Optical fibers with a diameter of 50 microns provide good spatial resolution and generally acceptable light levels. Larger diameter optical fibers provide more light, but at the expense of less resolution. Smaller diameter fibers limit the number of photons traveling through the fiber, although several layers of smaller diameter fibers (7-20 microns) are also acceptable. 400 fibers can each transmit light through the elongated slot 16 in the grating 14, allowing 400 channels of data to be imaged by the instrument.

The detector 24 will commonly be a CCD or CID 2-D detector array, having commonly the ability to resolve 1028 x 516 pixels. These devices permit the simultaneous measurement of spectral distribution of a spatial profile. Output from the detector is commonly sent through a RS-232 bus connector to a detector controller and then on to a computer for data storage and analysis. Modern detectors offer full programmability in two dimensions, low noise, high quantum efficiency, high dynamic range, and reasonable readout speeds. Further, the configuration of the detectors may be changed by software, an important requirement for a multichannel spectrograph. This is particularly the case for CID detectors where individual pixels are addressable.

The high spatial resolution imaging spectrograph in accordance with the present invention requires no power input, has no moving parts, and is completely passive with no operating controls or adjustments. The various components can be assembled in an instrument enclosure having a footprint of 0.1 m^2 (1.1 ft^2) and a volume of less than 0.0198 m^3 (0.7 ft^3). Total weight for the system is approximately 10 pounds. In applications calling for additional channels of spatial resolution, the instrument as disclosed and illustrated in FIGURE 3 is linearly scalable upward or downward to the desired size.

In use, then, a high spatial resolution imaging spectrograph in accordance with the present invention is selected compatible with the spatial resolution requirements of the application. Light from the object(s) to be analyzed is brought to the instrument by means of an optical fiber ribbon, which is placed at the focus of the collimating mirror 10. Light from individual fibers passes through the elongated slit 16 in the grating 14 and falls onto the collimating mirror 10, which reflects the light in parallel beams onto the grating 14. Light diffracted by the grating is collected by the focusing mirror 12, which focuses the light as close as possible to the incoming light from the object and onto the turning mirror 20. Light then travels into the camera mirror 22, which then focuses the image in the plane of a detector 24.

In this design, the angle between incoming and outgoing rays onto the collimating mirror 10 and the focusing mirror 12 is limited by the size of the turning mirror 20. in turn, the size of the turning mirror is defined by the spectral resolution required. The smaller the transverse dimension of the turning mirror, the smaller the number of independent channels of spectral information available and also the smaller the astigmatism introduced by spherical mirrors working slightly off axis, and, hence, the higher the spatial resolution of the instrument.

Referring now to FIGURE 4, in another preferred embodiment of the invention, a high spatial resolution imaging spectrograph may be designed with a combination mirror 26, which serves both as a collimating mirror and a focusing mirror. This mirror, and the other components of the instrument, are the same as discussed above in connection with FIGURE 3, although in this embodiment the grating works very close to the Littrow configuration. As discussed earlier, a high spatial resolution imaging spectrograph is limited in spectral resolution, or throughput, and this design optimizes throughput. As a result, the instrument can perform adequately with the use of a low dispersion plane diffraction grating, such as a 50 g/mm grating. Using such a low dispersion grating, the successive orders of the grating will be close to normal, allowing the functions performed by the collimating and focusing mirrors to be combined in a combination mirror 26. The use of a combination mirror allows the grating 14 to be positioned almost perpendicular to the optical axis of the instrument, a favorable configuration to introduce light through the grating. The ray path for a combination mirror system is illustrated in FIGURE 4. A combination mirror design for a high spatial resolution imaging spectrograph is especially appropriate for applications where the need for spectral resolution is low.

Referring now to FIGURE 5, a significant commercial application of the high spatial resolution spectrograph in accordance with the present invention is illustrated, showing an earth science remote imaging system. A reflecting telescope 28 of a conventional design is shown, with an optical fiber ribbon 30 mounted vertically at the primary focus 32 of an 20.32 cm (8 inch) primary mirror 34. The optical fiber ribbon 30 consists, for example, of 400 50 micron diameter optical fibers affixed together to form a vertical ribbon which is routed into the high spatial imaging spectrograph enclosure 36 and placed at the focus of the collimating mirror. The use of an optical fiber ribbon allows for the mechanical decoupling of the two instruments, affording flexibility in the design and use of the system.

The compact size and light weight of the earth science remote imaging system allows for its use in satellites or aircraft for terrestrial and oceanographic remote sensing research. Further, the use of a flexible optical fiber ribbon between the spectrograph and the telescope provides a soft link between the instruments, which facilitates their placement in the narrow confines of an aircraft or a satellite.

In use, then, an airborne or spaceborne system images an elongated area of the ground or sea along the vertical direction of the instrument in order to achieve high definition analysis of features on the surface. Spectral data are then collected for each independent spatial channel in a time short enough to use the natural translation of the carrier in the direction perpendicular to the area as a scanning device.

Referring finally to FIGURES 6 and 7, a means to prevent stray light within a high spatial resolution imaging spectrograph is disclosed. An optical mask 38 is shown positioned in front of a collimating mirror 10 or a combination mirror 26, in the general shape of the turning mirror 20. The mask is carefully positioned in front of the mirror so as to suppress light which would fall on the turning mirror in the first pass of light from the collimating mirror, or combination mirror, to the grating. The mask is coated with a non-reflective coating to reduce light falling onto the turning mirror. Instead of a add-on mask as illustrated, the same effect can be achieved by coating an area of the collimating mirror or combination mirror with a non-reflective coating or etching the surface of the mirror.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, the invention is not be to be limited to the disclosed embodiments, but on the contrary is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

Claims

1. An imaging spectrograph comprising:

a first spherical mirror (10);
a second spherical mirror (12);
an optical grating (14) with an elongated slot opening (16) therein positioned to receive and direct radiation from said first spherical mirror to said second spherical mirror;
a light turning mirror (20) positioned adjacent said opening (16) and at the focus of said second spherical mirror (12) to receive radiation from said second spherical mirror;
a third spherical mirror (22) arranged to receive radiation from said light turning mirror (20); and light detection means (24) to receive light from said third spherical mirror (22);
whereby incoming radiation from an object (18) positioned at the focus of said first spherical mirror (10) passes through said opening to illuminate said first spherical mirror and to form a spectral image on said light detection means (14).

2. An imaging spectrograph comprising:

a first spherical mirror (26);
an optical grating (14) with an elongated slot opening (16) therein positioned to receive and direct radiation from said first spherical mirror (26) and return said radiation to said first spherical mirror (26);
a light turning mirror (20) positioned at an off-axis focus of said first spherical mirror (26);
a second spherical mirror (22) to receive radiation from said light turning mirror (20); and
light detection means (24) to receive light from said second spherical mirror (22);
whereby incoming radiation from an object positioned at the focus of said first spherical mirror (26) passes through said opening (16) to illuminate said first spherical mirror (26) and to form a spectral image on said light detection means (24).

3. The imaging spectrograph as in claim 1 or 2, wherein said elongated slot opening (16) is positioned approximately in the center of the grating (14).

4. The imaging spectrograph as in claim 3, wherein said grating (14) is a plane diffraction grating.

5. The imaging spectrograph as in claim 1 or 2, wherein said light turning mirror is a plane mirror positioned adjacent to the path of said incoming radiation.

6. The imaging spectrograph as in claim 1 or 2, wherein said light detection means (24) consists of a CCD 2-D detector.

7. The imaging spectrograph as in claim 1 or 2, wherein said light detection means (24) consists of a CID 2-D detector.

8. The imaging spectrograph as in claim 1 or 2, wherein an end of an optical fiber is positioned at said focus of said first spherical mirror (10), whereby light from a remotely positioned object gathered at the opposite end of the optical fiber may serve as said incoming radiation.

9. The imaging spectrograph as in claim 8, wherein a plurality of optical fibers is provided forming an optical fiber ribbon (30) whereby the incoming radiation consists of multiple channels of vertically displayed radiation and spatially separate, vertically displayed spectral images are formed on the light detection means. .

10. The imaging spectrograph as in claim 9, wherein one end of said optical fiber ribbon (30) is positioned at said focus of said first spherical mirror (10).

11. The imaging spectrograph as in claim 1 or 2, further comprising an optical mask positioned to suppress radiation falling on the light turning mirror in the first pass of light from the first spherical mirror (10;26) to the grating (14).

Patentansprüche

1. Abbildender Spektrograph mit:

einem ersten sphärischen Spiegel (10);
einem zweiten sphärischen Spiegel (12);
einem optischen Gitter (14) mit einer langgestreckten Schlitzöffnung (16) darin, das so angeordnet ist, daß es Strahlung von dem ersten sphärischen Spiegel empfängt und auf den zweiten sphärischen Spiegel richtet;
einem Lichtumlenkspiegel (20), der benachbart zu der Öffnung (16) und in dem Brennpunkt des zweiten sphärischen Spiegels (12) angeordnet ist, um Strahlung von dem zweiten sphärischen Spiegel zu empfangen;
einem dritten sphärischen Spiegel (22), der so angeordnet ist, daß er Strahlung von dem Lichtumlenkspiegel (20) empfängt; und einer Lichterfassungseinrichtung (24) zum Empfangen von Licht von dem dritten sphärischen Spiegel (22);
wodurch Strahlung, die von einem Objekt (18) kommt, das in dem Brennpunkt des ersten sphärischen Spiegels (10) angeordnet ist, durch die Öffnung hindurchgeht, um den ersten sphärischen Spiegel zu beleuchten und eine Spektralabbildung auf der Lichterfassungseinrichtung (24) zu bilden.

2. Abbildender Spektrograph mit:

einem ersten sphärischen Spiegel (26);
einem optischen Gitter (14) mit einer langgestreckten Schlitzöffnung (16) darin, das so angeordnet ist, daß es Strahlung von dem ersten sphärischen Spiegel (26) empfängt und richtet und die Strahlung zu dem ersten sphärischen Spiegel (26) zurückleitet;
einem Lichtumlenkspiegel (20), der in einem achsenversetzten Brennpunkt des ersten sphärischen Spiegels (26) angeordnet ist;
einem zweiten sphärischen Spiegel (22) zum Empfangen von Strahlung von dem Lichtumlenkspiegel (20); und
einer Lichterfassungseinrichtung (24) zum Empfangen von Licht von dem zweiten sphärischen Spiegel (22);
wodurch Strahlung, die von einem Objekt kommt, das in dem Brennpunkt des ersten sphärischen Spiegels (26) angeordnet ist, durch die Öffnung (16) hindurchgeht, um den ersten sphärischen Spiegel (26) zu beleuchten und eine Spektralabbildung auf der Lichterfassungseinrichtung (24) zu bilden.

3. Abbildender Spektrograph nach Anspruch 1 oder 2, wobei die langgestreckte Schlitzöffnung (16) ungefähr in dem Zentrum des Gitters (14) angeordnet ist.

4. Abbildender Spektrograph nach Anspruch 3, wobei das Gitter (14) ein ebenes Beugungsgitter ist.

5. Abbildender Spektrograph nach Anspruch 1 oder 2, wobei der Lichtumlenkspiegel ein ebener Spiegel ist, der benachbart zu dem Weg der ankommenden Strahlung angeordnet ist.

6. Abbildender Spektrograph nach Anspruch 1 oder 2, wobei die Lichterfassungseinrichtung (24) aus einem zweidimensionalen CCD-Detektor besteht.

7. Abbildender Spektrograph nach Anspruch 1 oder 2, wobei die Lichterfassungseinrichtung (24) aus einem zweidimensionalen CID-Detektor besteht.

8. Abbildender Spektrograph nach Anspruch 1 oder 2, wobei ein Ende einer Lichtleitfaser in dem Brennpunkt des ersten sphärischen Spiegels (10) angeordnet ist, wodurch Licht aus einem entfernt angeordneten Objekt, das an dem entgegengesetzten Ende der Lichtleitfaser gesammelt wird, als die ankommende Strahlung dienen kann.

9. Abbildender Spektrograph nach Anspruch 8, wobei eine Vielzahl von Lichtleitfasern vorgesehen ist, die ein Lichtleitfaserband (30) bilden, wodurch die ankommende Strahlung aus mehreren Kanälen vertikal dargestellter Strahlung besteht und räumlich separate, vertikal dargestellte Spektralabbildungen auf der Lichterfassungseinrichtung gebildet werden.

10. Abbildender Spektrograph nach Anspruch 9, wobei ein Ende des Lichtleitfaserbandes (30) in dem Brennpunkt des ersten sphärischen Spiegels (10) angeordnet ist.

11. Abbildender Spektrograph nach Anspruch 1 oder 2, weiter mit einer optischen Maske, die so angeordnet ist, daß bei dem ersten Gang von Licht von dem ersten sphärischen Spiegel (10; 26) zu dem Gitter (14) auf den Lichtumlenkspiegel fallende Strahlung unterdrückt wird.

Revendications

1. Spectrographe imageur comprenant un premier miroir sphérique (10), un second miroir sphérique (12), un réseau optique (14) pourvu d'une ouverture en forme de fente allongée (16), ce réseau étant disposé de manière à recevoir et diriger une radiation en provenance du premier miroir sphérique vers le second miroir sphérique, un miroir de déviation de la lumière (20) placé à proximité de l'ouverture (16) et à l'endroit du foyer du second miroir sphérique (12) de manière à recevoir la radiation provenant du second miroir sphérique, un troisième miroir sphérique (22) disposé de manière à recevoir la radiation provenant du miroir de déviation de la lumière (20), et un moyen (24) de détection de lumière pour recevoir la lumière provenant du troisième miroir sphérique (22), de telle façon que la radiation arrivant d'un objet (18) placé à l'endroit du foyer du premier miroir sphérique (10) passe à travers l'ouverture pour illuminer le premier miroir sphérique et pour former une image spectrale sur le moyen détecteur de lumière (24).

2. Spectrographe imageur comprenant un premier miroir sphérique (26), un réseau optique (14) pourvu d'une ouverture en forme de fente allongée (16), ce réseau étant disposé de manière à recevoir et diriger une radiation en provenance du premier miroir sphérique (26) et à retourner cette radiation vers le premier miroir sphérique (26), un miroir de déviation de lumière (20) disposé à l'endroit d'un foyer, décalé par rapport à l'axe, du premier miroir sphérique (26), un second miroir sphérique (22) disposé de manière à recevoir la radiation provenant du miroir de déviation de la lumière (20), et un moyen (24) de détection de lumière pour recevoir la lumière provenant du second miroir sphérique (22), de telle façon que la radiation arrivant d'un objet placé à l'endroit du foyer du premier miroir sphérique (26) passe à travers l'ouverture (16) pour illuminer le premier miroir sphérique (26) et pour former une image spectrale sur le moyen détecteur de lumière (24).

3. Spectrographe imageur suivant l'une quelconque des revendications 1 ou 2 caractérisé en ce que l'ouverture (16) en forme de fente allongée est située approximativement au centre du réseau (14).

4. Spectrographe imageur suivant la revendication 3 caractérisé en ce que le réseau (14) est un réseau de diffraction plan.

5. Spectrographe imageur suivant l'une quelconque des revendications 1 ou 2 caractérisé en ce que le miroir de déviation de lumière est un miroir plan situé à proximité du trajet de la radiation arrivant.

6. Spectrographe imageur suivant l'une quelconque des revendications 1 ou 2 caractérisé en ce que le moyen détecteur de lumière (24) cst constitué par un détecteur bidimensionnel du type CCD.

7. Spectrographe imageur suivant l'une quelconque des revendications l ou 2 caractérisé en ce que le moyen détecteur de lumière (24) est constitué par un détecteur bidimensionnel du type CID.

8. Spectrographe imageur suivant l'une quelconque des revendications 1 ou 2 caractérisé en ce qu'une extrémité d'une fibre optique est située à l'endroit du foyer du premier miroir sphérique (10) si bien que la lumière provenant d'un objet se trouvant à distance, recueillie à l'extrémité opposée de la fibre optique, peut servir en tant que radiation arrivant.

9. Spectrographe imageur suivant la revendication 8 caractérisé en ce qu'une pluralité de fibres optiques sont prévues pour fonner un ruban de fibres optiques (30) de telle façon que la radiation arrivant soit constituée de canaux multiples de radiations affichées verticalement et que des images spectrales séparées spatialement et affichées verticalement soient formées sur le moyen détecteur de lumière.

10. Spectrographe imageur suivant la revendication 9

caractérisé en ce qu'une extrémité du ruban de fibres optiques (30) est située à l'endroit du foyer du premier miroir sphérique (10).

11. Spectrographe imageur suivant l'une quelconque des revendications 1 ou 2 caractérisé en ce qu'il comprend en outre un masque optique placé de manière à supprimer une radiation tombant sur le miroir de déviation de lumière lors du premier passage de la lumière du premier miroir sphérique (10; 26) jusqu'au réseau (14).

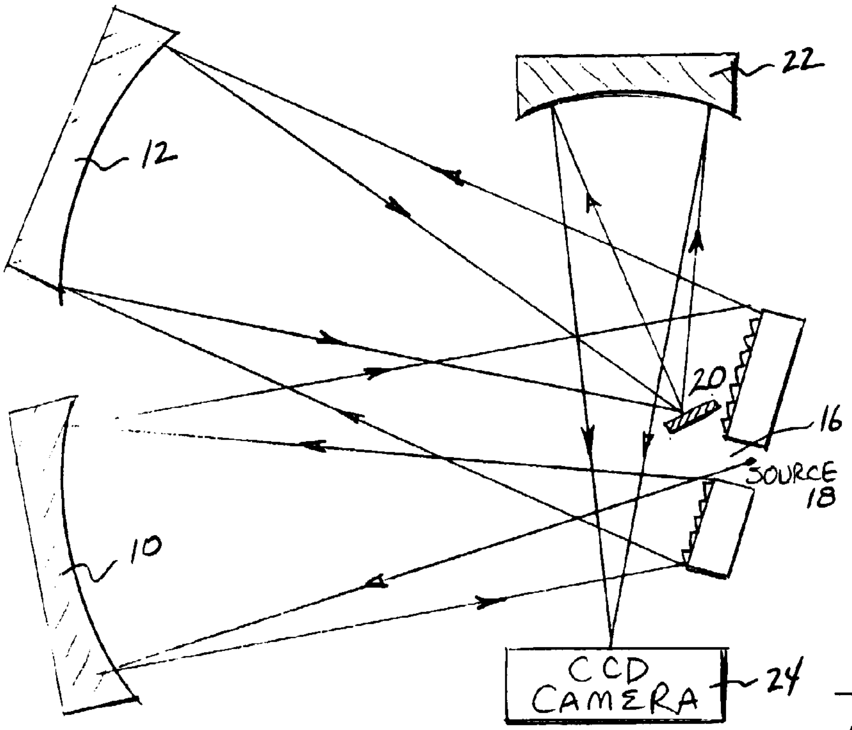

Fig. 3

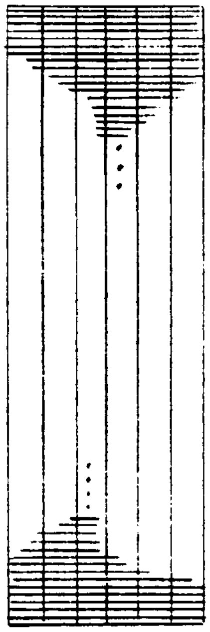

Fig. 2

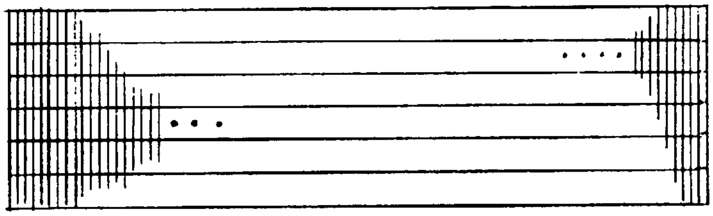

Fig. 1

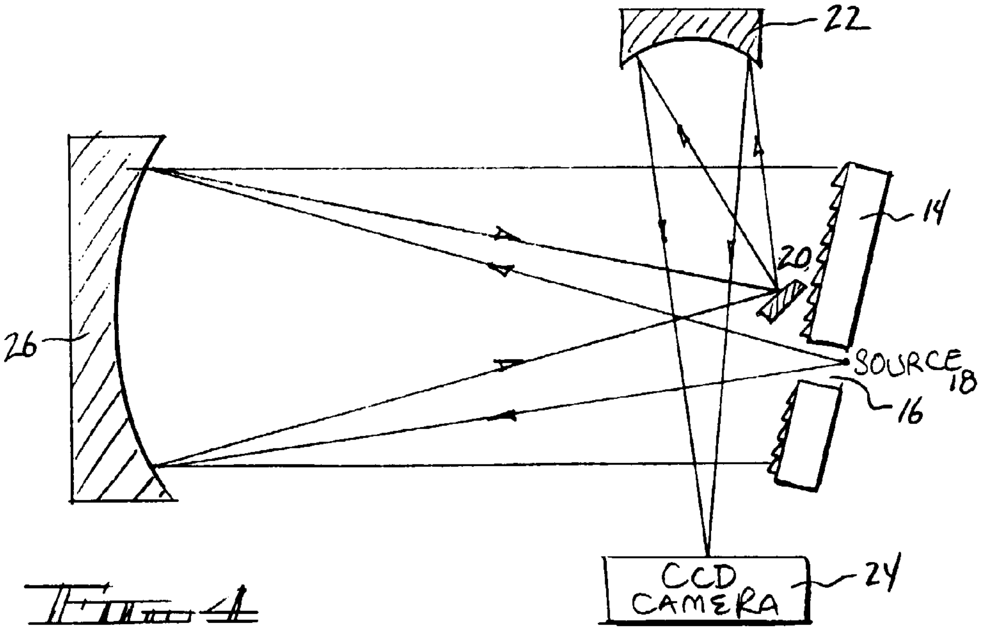

Fig. 4

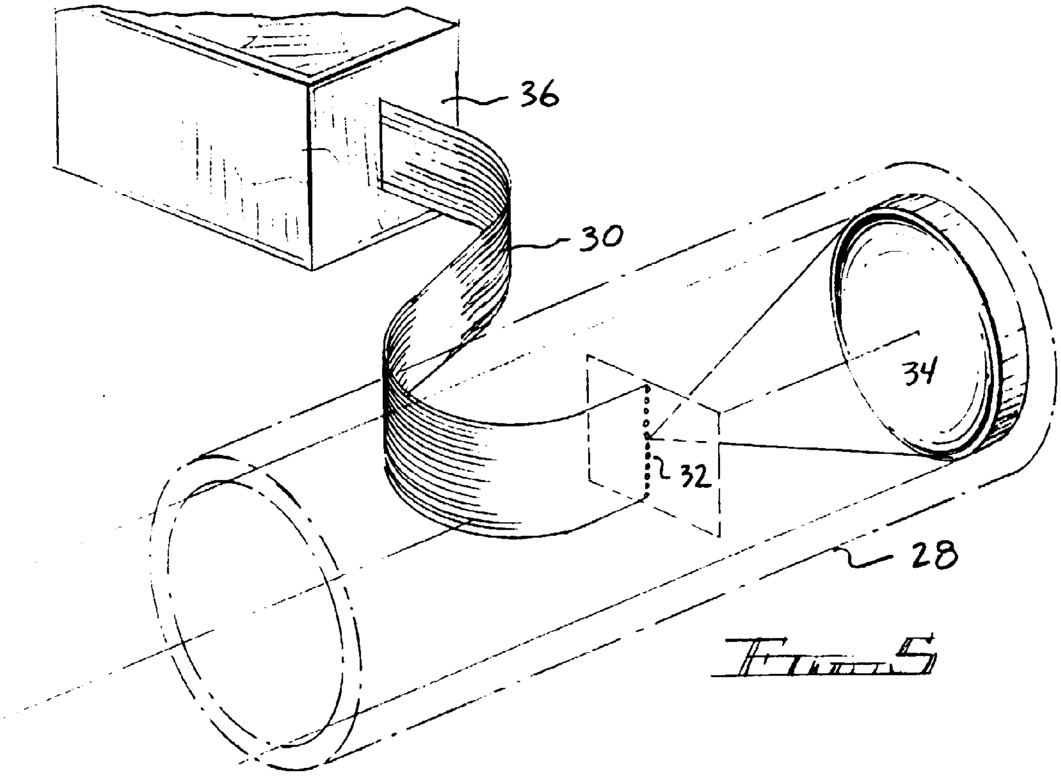

Fig. 5

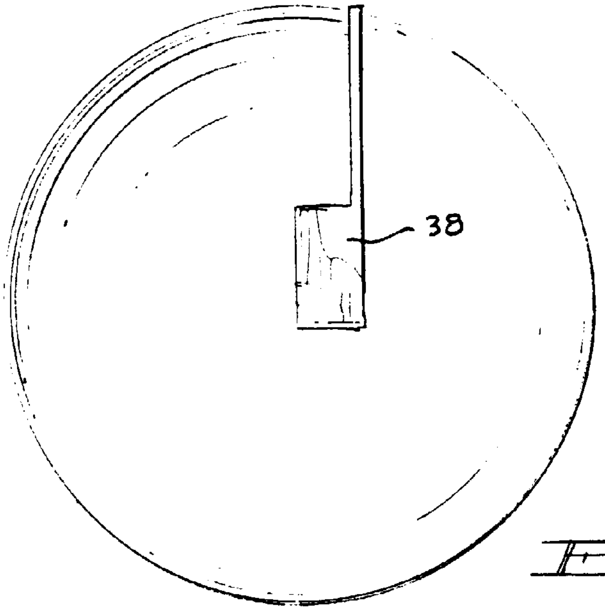

Fig. 6

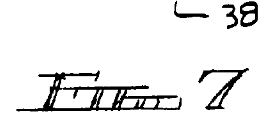

Fig. 7